Search of the Z' Boson

The Z′ boson may play an interesting role in the interaction between dark and visible matter, (i.e., it could be a kind of mediator between the two forms of matter). [22]

The research was a collaborative effort within the Dark Energy Survey, led by the Milky Way Working Group, with substantial contributions from junior members including Sidney Mau, an undergraduate at the University of Chicago, and Mitch McNanna, a graduate student at UW-Madison. [21]

Scientists are hoping to understand one of the most enduring mysteries in cosmology by simulating its effect on the clustering of galaxies. [20]

The U.S. Department of Energy has approved nearly $1 million in funding for the research team, which has been tasked with leveraging large-scale computer simulations and developing new statistical methods to help us better understand these fundamental forces. [19]

According to a new study, they could also potentially detect dark matter, if dark matter is composed of a particular kind of particle called a "dark photon." [18]

A global team of scientists, including two University of Mississippi physicists, has found that the same instruments used in the historic discovery of gravitational waves caused by colliding black holes could help unlock the secrets of dark matter, a mysterious and as-yet-unobserved component of the universe. [17]

The lack of so-called "dark photons" in electron-positron collision data rules out scenarios in which these hypothetical particles explain the muon's magnetic moment. [16]

By reproducing the complexity of the cosmos through unprecedented simulations, a new study highlights the importance of the possible behaviour of very high-energy photons. In their journey through intergalactic magnetic fields, such photons could be transformed into axions and thus avoid being absorbed. [15]

Scientists have detected a mysterious X-ray signal that could be caused by dark matter streaming out of our Sun's core.

Hidden photons are predicted in some extensions of the Standard Model of particle physics, and unlike WIMPs they would interact electromagnetically with normal matter.

In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter.

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

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Author: George Rajna

The Big Bang

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

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Belle II yields the first results: In search of the Z′ boson

The Belle II experiment has been collecting data from physical measurements for about one year. After several years of rebuilding work, both the SuperKEKB electron–positron accelerator and the Belle II detector have been improved compared with their predecessors in order to achieve a 40-fold higher data rate.

Scientists at 12 institutes in Germany are involved in constructing and operating the detector, developing evaluation algorithms and analyzing the data. The Max Planck Institute for Physics made a substantial contribution to the development of the highly sensitive innermost detector, the Pixel Vertex Detector.

With the help of Belle II, scientists are looking for traces of new physics that could explain the unequal occurrence of matter and antimatter and the mysterious dark matter. One of the so-far undiscovered particles that the Belle II detector is looking for is the Z′ boson—a variant of the Z boson, which acts as an exchange particle for the weak interaction.

As far as we know, about 25% of the universe consists of dark matter, whereas visible matter accounts for just under 5% of the energy budget. Both forms of matter attract each other through gravity. Dark matter thus forms a kind of template for the distribution of visible matter. This can be seen, for example, in the arrangement of galaxies in the universe.

Link between dark and normal matter

The Z′ boson may play an interesting role in the interaction between dark and visible matter, (i.e., it could be a kind of mediator between the two forms of matter). The Z′ boson can—at least theoretically—result from the collision of electrons (matter) and positrons (anti-matter) in the SuperKEKB and then decay into invisible dark matter particles.

The Z′ boson can thus help scientists to understand the behavior of dark matter. What's more, the discovery of the Z′ boson could also explain other observations that are not consistent with the standard model, the fundamental theory of particle physics.

Important clue: Detection of muon pairs

But how can the Z′ boson be detected in the Belle II detector? Not directly—that much is sure. Theoretical models and simulations predict that the Z′ boson could reveal itself through interactions with muons, the heavier relatives of electrons. If scientists discover an unusually high number of muon pairs of opposite charge after the electron/positron collisions as well as unexpected deviations in energy and momentum conservation, this would be an important indication of the Z′ boson.

However, the new Belle II data has not yet provided any indication of the Z′ boson. But with the new data, the scientists can limit the mass and coupling strengths of the Z′ boson with previously unattainable accuracy.

More data, more precise analyses

"Despite the still small amount of data, we can now make measurements that have never been done before," says the spokesperson of the German groups, Dr. Thomas Kuhr from the Ludwig Maximilian University of Munich. "This underlines the important role of the Belle II experiment in the study of elementary particles."

These initial results come from the analysis of a small amount of data collected during the start-up phase of SuperKEKB in 2018. Belle II went into full operation on March 25, 2019. Since then, the experiment has been collecting data while continuously improving the collision rate of electrons and positrons.

If the experiment is perfectly tuned, it will provide considerably more data than in the recently published analyses. The physicists thus hope to gain new insights into the nature of dark matter and other unanswered questions. [22]

The Milky Way's satellites help reveal link between dark matter halos and galaxy formation

Just as the sun has planets and the planets have moons, our galaxy has satellite galaxies, and some of those might have smaller satellite galaxies of their own. To wit, the Large Magellanic Cloud (LMC), a relatively large satellite galaxy visible from the Southern Hemisphere, is thought to have brought at least six of its own satellite galaxies with it when it first approached the Milky Way, based on recent measurements from the European Space Agency's Gaia mission.

Astrophysicists believe that dark matter is responsible for much of that structure, and now researchers at the Department of Energy's SLAC National Accelerator Laboratory and the Dark Energy Survey have drawn on observations of faint galaxies around the Milky Way to place tighter constraints on the connection between the size and structure of galaxies and the dark matter halos that surround them. At the same time, they have found more evidence for the existence of LMC satellite galaxies and made a new prediction: If the scientists' models are correct, the Milky Way should have an additional 150 or more very faint satellite galaxies awaiting discovery by next-generation projects such as the Vera C. Rubin Observatory's Legacy Survey of Space and Time.

The new study, forthcoming in the *Astrophysical Journal* and available as a preprint here, is part of a larger effort to understand how dark matter works on scales smaller than our galaxy, said Ethan Nadler, the study's first author and a graduate student at the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) and Stanford University.

"We know some things about dark matter very well—how much dark matter is there, how does it cluster—but all of these statements are qualified by saying, yes, that is how it behaves on scales larger than the size of our local group of galaxies," Nadler said. "And then the question is, does that work on the smallest scales we can measure?"

Shining galaxies' light on dark matter

Astronomers have long known the Milky Way has satellite galaxies, including the Large Magellanic Cloud, which can be seen by the naked eye from the Southern Hemisphere, but the number was thought to be around just a dozen or so until around the year 2000. Since then, the number of observed satellite galaxies has risen dramatically. Thanks to the Sloan Digital Sky Survey and more recent discoveries by projects including the Dark Energy Survey (DES), the number of known satellite galaxies has climbed to about 60.

Such discoveries are always exciting, but what's perhaps most exciting is what the data could tell us about the cosmos. "For the first time, we can look for these satellite galaxies across about three-quarters of the sky, and that's really important to several different ways of learning about dark matter and galaxy formation," said Risa Wechsler, director of KIPAC. Last year, for example, Wechsler, Nadler and colleagues used data on satellite galaxies in conjunction with computer simulations to place much tighter limits on dark matter's interactions with ordinary matter.

Now, Wechsler, Nadler and the DES team are using data from a comprehensive search over most of the sky to ask different questions, including how much dark matter it takes to form a galaxy, how many satellite galaxies we should expect to find around the Milky Way and whether galaxies can bring their own satellites into orbit around our own—a key prediction of the most popular model of dark matter.

Hints of galactic hierarchy

The answer to that last question appears to be a resounding "yes."

The possibility of detecting a hierarchy of satellite galaxies first arose some years back when DES detected more satellite galaxies in the vicinity of the Large Magellanic Cloud than they would have expected if those satellites were randomly distributed throughout the sky. Those observations are particularly interesting, Nadler said, in light of the Gaia measurements, which indicated that six of these satellite galaxies fell into the Milky Way with the LMC.

To study the LMC's satellites more thoroughly, Nadler and team analyzed computer simulations of millions of possible universes. Those simulations, originally run by Yao-Yuan Mao, a former graduate student of Wechsler's who is now at Rutgers University, model the formation of dark matter structure that permeates the Milky Way, including details such as smaller dark matter clumps within the Milky Way that are expected to host satellite galaxies. To connect dark matter to galaxy formation, the researchers used a flexible model that allows them to account for uncertainties in the current understanding of galaxy formation, including the relationship between galaxies' brightness and the mass of dark matter clumps within which they form.

An effort led by the others in the DES team, including former KIPAC students Alex Drlica-Wagner, a Wilson Fellow at Fermilab and an assistant professor of astronomy and astrophysics at the University of Chicago, and Keith Bechtol, an assistant professor of physics at the University of

Wisconsin-Madison, and their collaborators produced the crucial final step: a model of which satellite galaxies are most likely to be seen by current surveys, given where they are in the sky as well as their brightness, size and distance.

Those components in hand, the team ran their model with a wide range of parameters and searched for simulations in which LMC-like objects fell into the gravitational pull of a Milky Way-like galaxy. By comparing those cases with galactic observations, they could infer a range of astrophysical parameters, including how many satellite galaxies should have tagged along with the LMC. The results, Nadler said, were consistent with Gaia observations: Six satellite galaxies should currently be detected in the vicinity of the LMC, moving with roughly the right velocities and in roughly the same places as astronomers had previously observed. The simulations also suggested that the LMC first approached the Milky Way about 2.2 billion years ago, consistent with high-precision measurements of the motion of the LMC from the Hubble Space Telescope.

Galaxies yet unseen

In addition to the LMC findings, the team also put limits on the connection between dark matter halos and galaxy structure. For example, in simulations that most closely matched the history of the Milky Way and the LMC, the smallest galaxies astronomers could currently observe should have stars with a combined mass of around a hundred suns, and about a million times as much dark matter. According to an extrapolation of the model, the faintest galaxies that could ever be observed could form in halos up to a hundred times less massive than that.

And there could be more discoveries to come: If the simulations are correct, Nadler said, there are around 100 more satellite galaxies—more than double the number already discovered—hovering around the Milky Way. The discovery of those galaxies would help confirm the researchers' model of the links between dark matter and galaxy formation, he said, and likely place tighter constraints on the nature of dark matter itself.

The research was a collaborative effort within the Dark Energy Survey, led by the Milky Way Working Group, with substantial contributions from junior members including Sidney Mau, an undergraduate at the University of Chicago, and Mitch McNanna, a graduate student at UW-Madison. The research was supported by a National Science Foundation Graduate Fellowship, by the Department of Energy's Office of Science through SLAC, and by Stanford University. [21]

Dark matter clusters could reveal nature of dark energy

Scientists are hoping to understand one of the most enduring mysteries in cosmology by simulating its effect on the clustering of galaxies.

That mystery is dark energy – the phenomenon that scientists hypothesise is causing the universe to expand at an ever-faster rate. No-one knows anything about dark energy, except that it could be, somehow, blowing pretty much everything apart.

Meanwhile, dark energy has an equally shady cousin – dark matter. This invisible substance appears to have been clustering around galaxies, and preventing them from spinning themselves apart, by lending them an extra gravitational pull.

Such a clustering effect is in competition with dark energy's accelerating expansion. Yet studying the precise nature of this competition might shed some light on dark energy.

"Many dark energy models are already ruled out with current data," said Dr. Alexander Mead, a cosmologist at the University of British Columbia in Vancouver, Canada, who is working on a project called Halo modelling. "Hopefully in future we can rule more out."

Gravitational lensing

Currently, the only way dark matter can be observed is by looking for the effects of its gravitational pull on other matter and light. The intense gravitational field it produces can cause light to distort and bend over large distances – an effect known as gravitational lensing.

By mapping the dark matter in distant parts of the cosmos, scientists can work out how much dark matter clustering there is – and in principle how that clustering is being affected by dark energy.

The link between gravitational lensing and dark matter clustering is not straightforward, however. To interpret the data from telescopes, scientists must refer to detailed cosmological models – mathematical representations of complex systems.

Dr. Mead is developing a clustering model that he hopes will have enough accuracy to distinguish between different dark-energy hypotheses.

"An analogy I like a lot is with turbulence. In turbulent fluid flow you can talk about currents and eddies, which are nice words, but the reality of how fluid in a pipe goes from flowing calmly to flowing in a turbulent fashion is extremely complicated."

Fifth force

One of the more exotic theories is that dark energy is the result of a hitherto undetected fifth force, in addition to nature's four known forces—gravity, electromagnetism, and the strong and weak nuclear forces inside atoms.

A more common hypothesis for dark energy, however, is known as the cosmological constant, which was put forward by Albert Einstein as part of his general theory of relativity. It is often believed to describe an all-pervading sea of virtual particles that are continually popping into and out of existence throughout the universe.

One way to rule out the cosmological constant hypothesis, of course, is to prove that dark energy is not constant at all. This is the goal of Dr. Pier Stefano Corasaniti of the Paris Observatory in France, who – in a project called EDECS – is approaching dark-matter clustering from a different direction.

Instead of attempting to model clustering from gravitational lensing data, he is beginning specifically with a dynamical – that is, not constant – hypothesis of dark energy, and trying to predict how dark matter would cluster if this was the case.

Pushing the limits

There are, in principle, infinite ways dark energy can vary in space and time, although many theories have already been ruled out by existing observations. Dr. Corasaniti is focussing his simulations on types of dynamical dark energy that push at the edges of these observational limits, paving the way for tests with future experiments.

The simulations, which trace the evolution of numerous, "N-body' dark matter particles, require supercomputers running for long periods of time, processing several petabytes (one thousand million million bytes) of data.

"We have run among the largest cosmological N-body simulations ever realised," Dr. Corasaniti said.

Dr. Corasaniti's simulations predict that the way dark energy evolves over time ought to affect dark matter clustering. This, in turn, alters the efficiency with which galaxies form in ways that would not be the case with constant dark energy.

The predictions his models are making could be tested with the help of forthcoming telescopes such as the Large Synoptic Survey Telescope in Chile and the Square Kilometre Array in Australia and South Africa, as well as by satellite missions such as Euclid (EUropean Cooperation for LIghtning Detection) and WFIRST (Wide Field Infrared Survey Telescope).

"If dark energy turns out to be a dynamical phenomenon this will have a profound implication not only on cosmology, but on our understanding of fundamental physics," said Dr. Corasaniti. [20]

Large-scale simulations could shed light on the 'dark' elements that make up most of our cosmos

If you only account for the matter we can see, our entire galaxy shouldn't exist. The combined gravitational pull of every known moon, planet, and star should not have been strong enough to produce a system as dense and complex as the Milky Way.

So what's held it all together?

Scientists believe there is a large amount of additional matter in the universe that we can't observe directly – so-called "dark matter." While it is not known what dark matter is made of, its effects on light and gravity are apparent in the very structure of our galaxy. This, combined with the even more mysterious "dark energy" thought to be speeding up the universe's expansion, could make up as much as 96 percent of the entire cosmos.

In an ambitious effort directed by Argonne National Laboratory, researchers at the Biocomplexity Institute of Virginia Tech are now attempting to estimate key features of the universe, including its relative distributions of dark matter and dark energy. The U.S. Department of Energy has approved nearly $1 million in funding for the research team, which has been tasked with leveraging large-scale computer simulations and developing new statistical methods to help us better understand these fundamental forces.

To capture the impact of dark matter and dark energy on current and future scientific observations, the research team plans to build on some of the powerful predictive technologies that have been employed by the Biocomplexity Institute to forecast the global spread of diseases like Zika and Ebola. Using observational data from sources like the Dark Energy Survey, scientists will attempt to better understand how these "dark" elements have influenced the evolution of the universe.

"It sounds somewhat incredible, but we've done similar things in the past by combining statistical methods with supercomputer simulations, looking at epidemics," said Dave Higdon, a professor in the Biocomplexity Institute's Social and Decision Analytics Laboratory and a faculty member in the Department of Statistics, part of the Virginia Tech College of Science.

"Using statistical methods to combine input data on population, movement patterns, and the surrounding terrain with detailed simulations can forecast how health conditions in an area will evolve quite reliably—it will be an interesting test to see how well these same principles perform on a cosmic scale."

If this effort is successful, results will benefit upcoming cosmological surveys and may shed light on a number of mysteries regarding the makeup and evolution of dark matter and dark energy. What's more, by reverse engineering the evolution of these elements, they could provide unique insights into more than 14 billion years of cosmic history. [19]

Gravitational wave detectors to search for dark matter

Gravitational wave detectors might be able to detect much more than gravitational waves. According to a new study, they could also potentially detect dark matter, if dark matter is composed of a particular kind of particle called a "dark photon." In the future, LIGO (Laser Interferometer Gravitational Wave Observatory) scientists plan to implement a search for dark photons, which will include certain previously unexplored regions of the dark photon parameter space.

A team of physicists, Aaron Pierce, Keith Riles, and Yue Zhao from the University of Michigan, have reported their proposal for using gravitational wave detectors to search for dark matter in a recent paper published in *Physical Review Letters*.

"This proposal nicely bridges the newly born field of gravitational wave astronomy with that of particle physics," Zhao told *Phys.org*. "Without any modifications, a gravitational wave detector can be used as a very sensitive direct dark matter detector, with the potential for a five-sigma discovery of dark matter."

As the physicists explain in their paper, if dark photons have a very light mass, then they can be considered to behave like an oscillating background field, with the oscillation frequency determined by their mass. Gravitational wave detectors could potentially detect these oscillations because the oscillations may affect test objects placed in the gravitational wave detectors. For example, if two test objects located at different positions in the detector experience different displacements, this difference may be due to the relative phase of the dark photonfield's oscillations at these different positions.

The physicists expect that both present Earth-based gravitational wave detectors such as LIGO, as well as future space-based gravitational wave detectors such as LISA (Laser Interferometer Space Antenna), will have the ability to search for dark photon dark matter. Using more than one detector would allow for cross-checking and better sensitivity.

In the future, the scientists plan to work on further developing the new dark matter search method and determining exactly what kind of signal a gravitational wave detector would receive if a dark photon were nearby.

"We plan to push this work well beyond a theoretical proposal," Zhao said. "First, we plan to carry out the data analysis using a simplified signal model and a straightforward search algorithm. Then we will gradually refine our search method and include a detailed simulation of the signal and detector response." [18]

Gravitational wave detectors could shed light on dark matter

A global team of scientists, including two University of Mississippi physicists, has found that the same instruments used in the historic discovery of gravitational waves caused by colliding black holes could help unlock the secrets of dark matter, a mysterious and as-yet-unobserved component of the universe.

The research findings by Emanuele Berti, UM associate professor of physics and astronomy, Shrobana Ghosh, a graduate student, and their colleagues appears in the September issue of Physical Review Letters, one of the most prestigious peer-reviewed academic journals in the field. "Stochastic and resolvable gravitational waves from ultralight bosons" is co-authored by fellow scientists Richard Brito, Enrico Barausse, Vitor Cardoso, Irina Dvorkin, Antoine Klein and Paolo Pani.

The nature of dark matter remains unknown, but scientists estimate that it is five times as abundant as ordinary matter throughout the universe.

"The nature of dark matter is one the greatest mysteries in physics," Berti said. "It is remarkable that we can now do particle physics – investigate the "very small" – by looking at gravitational-wave emission from black holes, the largest and simplest objects in the universe."

PRL is one of several publications produced by the American Physical Society and American Institute of Physics. It contains papers considered to represent significant advances in research, and therefore, published quickly in short, letter format for a broad audience of physicists.

This paper details calculations by the scientists, who work in Germany, France, Italy, Portugal and the U.S., show that gravitational-wave interferometers can be used to indirectly detect the presence of dark matter.

A companion paper by the team, "Gravitational wave searches for ultralight bosons with LIGO and LISA," also has been accepted and will appear in Physical Review D.

Calculations show that certain types of dark matter could form giant clouds around astrophysical black holes. If ultralight scalar particles exist in nature, fast-spinning black holes would trigger the growth of such scalar "condensates" at the expense of their rotational energy, producing a cloud that rotates around the black hole, now more slowly-spinning, and emits gravitational waves, pretty much like a giant lighthouse in the sky.

"One possibility is that dark matter consists of scalar fields similar to the Higgs boson, but much lighter than neutrinos," Pani said. "This type of dark matter is hard to study in particle accelerators, such as the Large Hadron Collider at CERN, but it may be accessible to gravitational-wave detectors."

The team led by Brito studied gravitational waves emitted by the "black hole plus cloud" system. Depending on the mass of the hypothetical particles, the signal is strong enough to be detected by the Laser Interferometer Gravitational-wave Observatory, with instruments in Louisiana and Washington, and its European counterpart Virgo, as well as by the future space mission Laser Interferometer Space Antenna.

"Surprisingly, gravitational waves from sources that are too weak to be individually detectable can produce a strong stochastic background," Brito said. "This work suggests that a careful analysis of the background in LIGO data may rule out – or detect – ultralight dark matter by gravitational-wave interferometers.

"This is a new, exciting frontier in astroparticle physics that could shed light on our understanding of the microscopic universe."

LIGO has been offline for a few months for upgrades. The team plans to announce new, exciting results from its second observing run soon.

"Our work shows that careful analysis of stochastic gravitational waves in the data they have already taken may be used to place interesting constraints on the nature of dark matter," Berti said.

This innovative work "confirms the high quality of the work in astroparticle physics and gravitationalwave astronomy done by members of the gravitational physics group at UM, widely recognized as one of the leaders in the field," said Luca Bombelli, chair and professor of physics and astronomy at Ole Miss. [17]

Synopsis: Dark Photon Conjecture Fizzles

The lack of so-called "dark photons" in electron-positron collision data rules out scenarios in which these hypothetical particles explain the muon's magnetic moment.

Dark photons sound like objects confused about their purpose, but in reality they are part of a comprehensive theory of dark matter. Researchers imagine that dark photons have photon-like interactions with other dark matter particles. And these hypothetical particles have recently gained interest because they might explain why the observed value of the muon's anomalous magnetic moment disagrees slightly with predictions. However, this muon connection now appears to have been ruled out by the BaBar Collaboration at the SLAC National Accelerator Laboratory in California. The researchers found no signal of dark photons in their electron-positron collision data.

Like the normal photon, the dark photon would carry an electromagnetic-like force between dark matter particles. It could also potentially have a weak coupling to normal matter, implying that dark photons could be produced in high-energy collisions. Previous searches have failed to find a signature, but they have generally assumed that dark photons decay into electrons or some other type of visible particle.

For their new search, the BaBar Collaboration considered a scenario in which a dark photon is created with a normal photon in an electron-positron collision and then decays into invisible particles, such as other dark matter particles. In this case, only one particle—the normal photon—would be detected, and it would carry less than the full energy from the collision. Such missingenergy events can occur in other ways, so the team looked for a "bump" or increase in events at a specific energy that would correspond to the mass of the dark photon. They found no such bump up to masses of 8 GeV. The null result conflicts with models in which a dark photon contribution brings the predicted muon magnetic moment in line with observations. [16]

Exchanges of identity in deep space

By reproducing the complexity of the cosmos through unprecedented simulations, a new study highlights the importance of the possible behaviour of very high-energy photons. In their journey through intergalactic magnetic fields, such photons could be transformed into axions and thus avoid being absorbed.

Like in a nail-biting thriller full of escapes and subterfuge, photons from far-off light sources such as blazars could experience a continuous exchange of identity in their journey through the universe. This would allow these very tiny particles to escape an enemy which, if encountered, would annihilate them. Normally, very high-energy photons (gamma rays) should "collide" with the background light emitted by galaxies and transform into pairs of matter and antimatter particles, as envisaged by the Theory of Relativity. For this reason, the sources of very high-energy gamma rays should appear significantly less bright than what is observed in many cases.

A possible explanation for this surprising anomaly is that light photons are transformed into hypothetical weakly interacting particles, "axions," which, in turn, would change into photons, all due to the interaction with magnetic fields. A part of the photons would escape interaction with the intergalactic background light that would make them disappear. The importance of this process is emphasised by a study published in Physical Review Letters, which recreated an extremely refined model of the cosmic web, a network of filaments composed of gas and dark matter present throughout the universe, and of its magnetic fields. These effects are now awaiting comparison with those obtained experimentally through Cherenkov Telescope Array new generation telescopes.

Through complex and unprecedented computer simulations made at the CSCS Supercomputing Centre in Lugano, scholars have reproduced the so-called cosmic web and its associated magnetic fields to investigate the theory that photons from a light source are transformed into axions, hypothetical elementary particles, on interacting with an extragalactic magnetic field. Axions could then be changed back into photons by interacting with other magnetic fields. Researchers Daniele Montanino, Franco Vazza, Alessandro Mirizzi and Matteo Viel write, "Photons from luminous bodies disappear when they encounter extragalactic background light (EBL). But if on their journey they head into these transformations as envisaged by these theories, it would explain why, in addition to giving very important information on processes that occur in the universe, distant celestial bodies are brighter than expected from an observation on Earth. These changes would, in fact, enable a greater number of photons to reach the Earth."

Thanks to the wealth of magnetic fields present in the cosmic web's filaments, which were recreated with the simulations, the conversion phenomenon would seem much more relevant than predicted by previous models: "Our simulations reproduce a very realistic picture of the cosmos' structure. From what we have observed, the distribution of the cosmic web envisaged by us would markedly increase the probability of these transformations." The next step in the research is to compare simulation results with the experimental data obtained through the use of the Cherenkov Telescope Array Observatories detectors, the new-generation astronomical observatories, one of which is positioned in the Canary Islands and the other in Chile. They will study the universe through very high-energy gamma rays. [15]

Astronomers may have detected the first direct evidence of dark matter

Scientists have detected a mysterious X-ray signal that could be caused by dark matter streaming out of our Sun's core.

Now scientists at the University of Leicester have identified a signal on the X-ray spectrum which appears to be a signature of 'axions' - a hypothetical dark matter particle that's never been detected before.

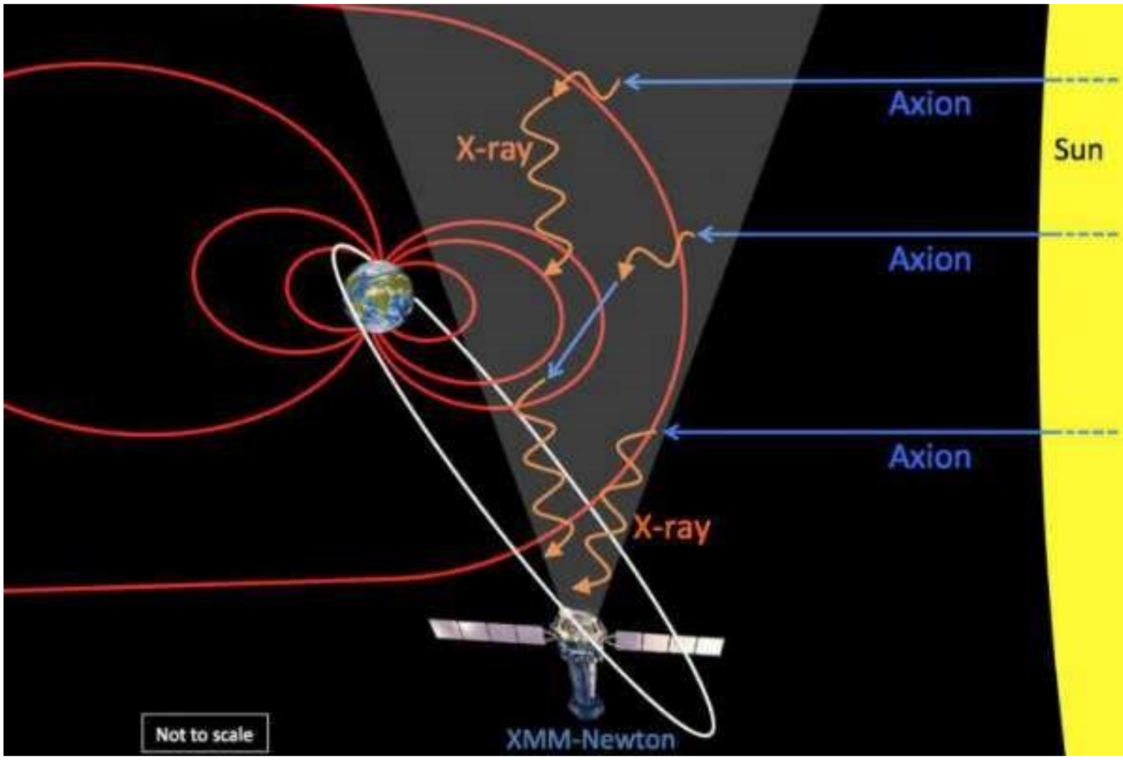
While we can't get too excited just yet - it will take years to confirm whether this signal really is dark matter - the discovery would completely change our understanding of how the Universe works. After all, dark matter is the force that holds our galaxies together, so learning more about it is pretty important.

The researchers first detected the signal while searching through 15 years of measurements taking by the European Space Agency's orbiting XMM-Newton space observatory.

Unexpectedly, they noticed that the intensity of X-rays recorded by the spacecraft rose by about 10% whenever XMM-Newton was at the boundary of Earth's magnetic field facing the Sun - even once they removed all the bright X-ray sources from the sky. Usually, that X-ray background is stable. "The X-ray background - the sky, after the bright X-ray sources are removed - appears to be unchanged whenever you look at it," said Andy Read, from the University of Leicester, one of the lead authors on the paper, in a press release. "However, we have discovered a seasonal signal in this X-ray background, which has no conventional explanation, but is consistent with the discovery of axions."

Researchers predict that axions, if they exist, would be produced invisibly by the Sun, but would convert to X-rays as they hit Earth's magnetic field. This X-ray signal should in theory be strongest when looking through the sunward side of the magnetic field, as this is where the Earth's magnetic field is strongest.

The next step is for the researchers to get a larger dataset from XMM-Newton and confirm the pattern they've seen in X-rays. Once they've done that, they can begin the long process of proving that they have, in fact, detecting dark matter streaming out of our Sun's core.



A sketch (not to scale) shows axions (blue) streaming out of the Sun and then converting into X-rays (orange) in the Earth's magnetic field (red). The X-rays are then detected by the XMM-Newton observatory. [13]

The axion is a hypothetical elementary particle postulated by the Peccei–Quinn theory in 1977 to resolve the strong CP problem in quantum chromodynamics (QCD). If axions exist and have low mass within a specific range, they are of interest as a possible component of cold dark matter. [14]

Hidden photons

Hidden photons are predicted in some extensions of the Standard Model of particle physics, and unlike WIMPs they would interact electromagnetically with normal matter. Hidden photons also have a very small mass, and are expected to oscillate into normal photons in a process similar to neutrino oscillation. Observing such oscillations relies on detectors that are sensitive to extremely small electromagnetic signals, and a number of these extremely difficult experiments have been built or proposed.

A spherical mirror is ideal for detecting such light because the emitted photons would be concentrated at the sphere's centre, whereas any background light bouncing off the mirror would pass through a focus midway between the sphere's surface and centre. A receiver placed at the centre could then pick up the dark-matter-generated photons, if tuned to their frequency – which is related to the mass of the incoming hidden photons – with mirror and receiver shielded as much as possible from stray electromagnetic waves.

Ideal mirror at hand

Fortunately for the team, an ideal mirror is at hand: a 13 m2 aluminium mirror used in tests during the construction of the Pierre Auger Observatory and located at the Karlsruhe Institute of Technology. Döbrich and co-workers have got together with several researchers from Karlsruhe, and the collaboration is now readying the mirror by adjusting the position of each of its 36 segments to minimize the spot size of the focused waves. They are also measuring background radiation within the shielded room that will house the experiment. As for receivers, the most likely initial option is a set of low-noise photomultiplier tubes for measurements of visible light, which corresponds to hidden-photon masses of about 1 eV/C^2. Another obvious choice is a receiver for gigahertz radiation, which corresponds to masses less than 0.001 eV/C^2; however, this latter set-up would require more shielding.

Dark matter composition research - WIMP

The WIMP (Weakly interactive massive particles) form a class of heavy particles, interacting slightly with matter, and constitute excellent candidates with the nonbaryonic dark matter. The neutralino postulated by the supersymetric extensions of the standard model of particle physics. The idea of supersymmetry is to associate each boson to a fermion and vice versa. Each particle is then given a super-partner, having identical properties (mass, load), but with a spin which differes by 1/2. Thus, the number of particles is doubled. For example, the photon is accompanied by a photino, the graviton by a gravitino, the electron of a selectron, etc. Following the impossibility to detect a 511 keV boson (the electron partner), the physicists had to re-examine the idea of an exact symmetry. Symmetry is 'broken' and superpartners have a very important mass. One of these superparticules called LSP (Lightest Supersymmetric Particle) is the lightest of all. In most of the supersymmetric theories (without violation of the R-parity) the LSP is a stable particle because it cannot disintegrate in a lighter element. It is of neutral color and electric charge and is then only sensitive to weak interaction (weak nuclear force). It is then an excellent candidate for the not-baryonic dark matter. [11]

Weakly interacting massive particles

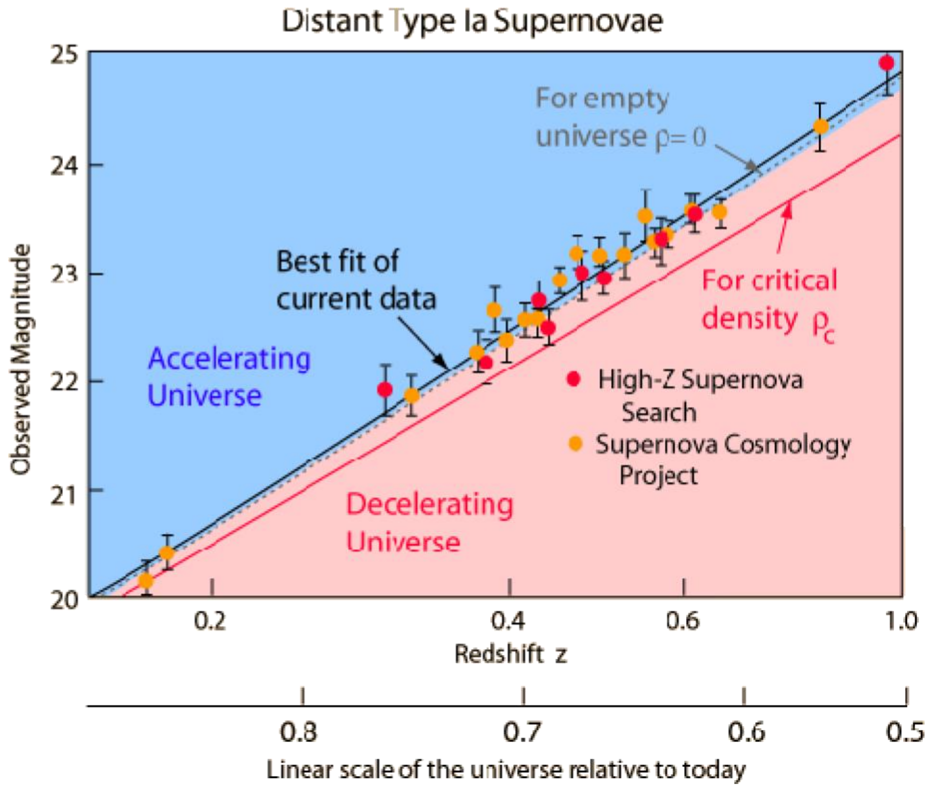
In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter. The term “WIMP” is given to a dark matter particle that was produced by falling out of thermal equilibrium with the hot dense plasma of the early universe, although it is often used to refer to any dark matter candidate that interacts with standard particles via a force similar in strength to the weak nuclear force. Its name comes from the fact that obtaining the correct abundance of dark matter today via thermal production requires a self-annihilation cross section, which is roughly what is expected for a new particle in the 100 GeV mass range that interacts via the electroweak force. This apparent coincidence is known as the “WIMP miracle”. Because supersymmetric extensions of the standard model of particle physics readily predict a new particle with these properties, a stable supersymmetric partner has long been a prime WIMP candidate. However, recent null results from direct detection experiments including LUX and SuperCDMS, along with the failure to produce evidence of supersymmetry in the Large Hadron Collider (LHC) experiment has cast doubt on the simplest WIMP hypothesis. Experimental efforts to detect WIMPs include the search for products of WIMP annihilation, including gamma

rays, neutrinos and cosmic rays in nearby galaxies and galaxy clusters; direct detection experiments designed to measure the collision of WIMPs with nuclei in the laboratory, as well as attempts to directly produce WIMPs in colliders such as the LHC. [10]

Evidence for an accelerating universe

One of the observational foundations for the big bang model of cosmology was the observed expansion of the universe. [9] Measurement of the expansion rate is a critical part of the study, and it has been found that the expansion rate is very nearly "flat". That is, the universe is very close to the critical density, above which it would slow down and collapse inward toward a future "big crunch". One of the great challenges of astronomy and astrophysics is distance measurement over the vast distances of the universe. Since the 1990s it has become apparent that type Ia supernovae offer a unique opportunity for the consistent measurement of distance out to perhaps 1000 Mpc. Measurement at these great distances provided the first data to suggest that the expansion rate of the universe is actually accelerating. That acceleration implies an energy density that acts in opposition to gravity which would cause the expansion to accelerate. This is an energy density which we have not directly detected observationally and it has been given the name "dark energy".

The type Ia supernova evidence for an accelerated universe has been discussed by Perlmutter and the diagram below follows his illustration in Physics Today.



The data summarized in the illustration above involve the measurement of the redshifts of the distant supernovae. The observed magnitudes are plotted against the redshift parameter z. Note

that there are a number of Type 1a supernovae around z=.6, which with a Hubble constant of 71 km/s/mpc is a distance of about 5 billion light years.

Equation

The cosmological constant Λ appears in Einstein's field equation [5] in the form of

$$R_{\mu\nu} - \frac{1}{2}R\,g_{\mu\nu} + \Lambda\,g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}\,,$$

where *R* and *g* describe the structure of spacetime, *T* pertains to matter and energy affecting that structure, and *G* and *c* are conversion factors that arise from using traditional units of measurement. When Λ is zero, this reduces to the original field equation of general relativity. When *T* is zero, the field equation describes empty space (the vacuum).

The cosmological constant has the same effect as an intrinsic energy density of the vacuum, ρ_{vac} (and an associated pressure). In this context it is commonly moved onto the right-hand side of the equation, and defined with a proportionality factor of 8π: $\Lambda = 8\pi\rho_{vac}$, where unit conventions of general relativity are used (otherwise factors of *G* and *c* would also appear). It is common to quote values of energy density directly, though still using the name "cosmological constant".

A positive vacuum energy density resulting from a cosmological constant implies a negative pressure, and vice versa. If the energy density is positive, the associated negative pressure will drive an accelerated expansion of the universe, as observed. (See dark energy and cosmic inflation for details.)

Explanatory models

Models attempting to explain accelerating expansion include some form of dark energy, dark fluid or phantom energy. The most important property of dark energy is that it has negative pressure which is distributed relatively homogeneously in space. The simplest explanation for dark energy is that it is a cosmological constant or vacuum energy; this leads to the Lambda-CDM model, which is generally known as the Standard Model of Cosmology as of 2003-2013, since it is the simplest model in good agreement with a variety of recent observations.

Dark Matter and Energy

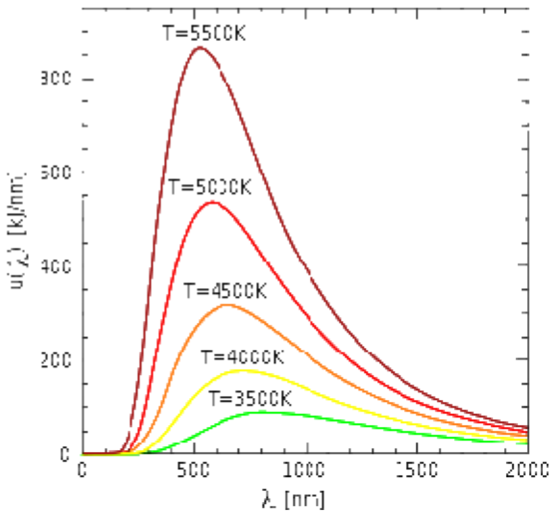
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant level. It is otherwise hypothesized to simply be matter that is not reactant to light. Instead, the existence and properties of dark matter are inferred from its gravitational effects on visible matter, radiation, and the large-scale structure of the universe. According to the Planck mission team, and based on the standard model of cosmology, the total mass–energy of the known universe contains 4.9% ordinary matter, 26.8% dark matter and 68.3% dark energy. Thus, dark matter is estimated to constitute 84.5% of the total matter in the universe, while dark energy plus dark matter constitute 95.1% of the total content of the universe. [6]

Cosmic microwave background

The cosmic microwave background (CMB) is the thermal radiation assumed to be left over from the "Big Bang" of cosmology. When the universe cooled enough, protons and electrons combined to form neutral atoms. These atoms could no longer absorb the thermal radiation, and so the universe became transparent instead of being an opaque fog. [7]

Thermal radiation

Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter. All matter with a temperature greater than absolute zero emits thermal radiation. When the temperature of the body is greater than absolute zero, interatomic collisions cause the kinetic energy of the atoms or molecules to change. This results in charge-acceleration and/or dipole oscillation which produces electromagnetic radiation, and the wide spectrum of radiation reflects the wide spectrum of energies and accelerations that occur even at a single temperature. [8]



Electromagnetic Field and Quantum Theory

Needless to say that the accelerating electrons of the steady stationary current are a simple demystification of the magnetic field, by creating a decreasing charge distribution along the wire, maintaining the decreasing U potential and creating the **A** vector potential experienced by the electrons moving by **v** velocity relative to the wire. This way it is easier to understand also the time dependent changes of the electric current and the electromagnetic waves as the resulting fields moving by c velocity.

It could be possible something very important law of the nature behind the self maintaining **E** accelerating force by the accelerated electrons. The accelerated electrons created electromagnetic fields are so natural that they occur as electromagnetic waves traveling with velocity c. It shows that the electric charges are the result of the electromagnetic waves diffraction.

One of the most important conclusions is that the electric charges are moving in an accelerated way and even if their velocity is constant, they have an intrinsic acceleration anyway, the so called spin, since they need at least an intrinsic acceleration to make possible they movement .

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing. Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution

Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions. [4]

Lorentz transformation of the Special Relativity

In the referential frame of the accelerating electrons the charge density lowering linearly because of the linearly growing way they takes every next time period. From the referential frame of the wire there is a parabolic charge density lowering.

The difference between these two referential frames, namely the referential frame of the wire and the referential frame of the moving electrons gives the relativistic effect. Important to say that the moving electrons presenting the time coordinate, since the electrons are taking linearly increasing way every next time period, and the wire presenting the geometric coordinate. The Lorentz transformations are based on moving light sources of the Michelson - Morley experiment giving a practical method to transform time and geometric coordinates without explaining the source of this mystery.

The real mystery is that the accelerating charges are maintaining the accelerating force with their charge distribution locally. The resolution of this mystery that the charges are simply the results of the diffraction patterns, that is the charges and the electric field are two sides of the same thing. Otherwise the charges could exceed the velocity of the electromagnetic field.

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

The Classical Relativistic effect

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field.
In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion.

Electromagnetic inertia and Gravitational attraction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass.

It looks clear that the growing acceleration results the relativistic growing mass - limited also with the velocity of the electromagnetic wave.

Since $E = hv$ and $E = mc^2$, $m = hv / c^2$ that is the m depends only on the v frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

If the mass is electromagnetic, then the gravitation is also electromagnetic effect caused by the accelerating Universe! The same charges would attract each other if they are moving parallel by the magnetic effect.

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force.

Electromagnetic inertia and mass

Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

Relativistic change of mass

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The frequency dependence of mass

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Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force. [1]

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

Gravity from the point of view of quantum physics

The Gravitational force

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Bing Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass rate Mp=1840 Me. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass.

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [2]

Conclusions

Researchers predict that axions, if they exist, would be produced invisibly by the Sun, but would convert to X-rays as they hit Earth's magnetic field. This X-ray signal should in theory be strongest when looking through the sunward side of the magnetic field, as this is where the Earth's magnetic field is strongest. The high frequency of the X-ray and the uncompensated Planck distribution makes the axion a good candidate to be dark matter.

Hidden photons are predicted in some extensions of the Standard Model of particle physics, and unlike WIMPs they would interact electromagnetically with normal matter.
In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter.
The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.
The electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together. [3]

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